random, opening the intestines under the microscope, and preserving the contents either as microscope slides or in capillary vials, I found that these ten specimens had eaten twenty-four entomostraca, all belonging to two species, descriptions of which I have in press, viz: *Cyclops thomasi* and *Diaptomus sicilis*—fourteen of the first and ten of the second.

Besides these I found only a few diatoms (*baccillaria*) in two of the fishes; a little fragment of a filament of an alga in one, and three rotifers (*Anuræa striata*) in another.

I will prepare a full account of the experiment, with a description of the developmental conditions of the fishes when they commenced to eat, and a full analysis of their food, as soon as I have time to do the work.

I am indebted to Mr. Clark for the specimens; to the Chicago Exposition Company for the use of the tank, and to the State of Illinois for the expenses of the experiment.

ILLINOIS STATE LABORATORY OF NATURAL HISTORY,
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NOTES ON THE BREEDING, FOOD, AND GREEN COLOR OF THE OYSTER.

By JOHN A. RYDER.

No mollusk known to the naturalists, it appears, is consumed in such vast quantities as our native oyster, the *Ostrea virginica* of Gmelin; hence its great economic importance and the scientific interest which it has recently awakened. It is vastly superior in flavor, size, and vigor of growth to the oyster of Europe, and is simulated and approached only by one old Continental form which I have seen, probably the *Ostrea rostralis* of Lamarck. The first attempt made in the artificial impregnation of the eggs of this noble mollusk was successful in the hands of our countryman, Prof. W. K. Brooks, of Johns Hopkins University, of Baltimore, who, in 1880, published a remarkable memoir on the subject in the annual report of Maj. T. B. Ferguson, one of the fish commissioners of Maryland. Professor Brooks' triumph was not, however, as complete as might have been desired, since his investigations have not yet led to the development of methods whereby the oyster could be propagated by purely artificial means, but his success was so far beyond what was attained by Dr. Davaine in his attempts at the artificial fertilization of the European oyster in 1851, that Brooks' achievement marks the most important era in the history of the subject. Others, as well as the writer, have repeated his experiments with more or less success, and the latter has been able to work out a portion of the developmental history of *Mya arenaria*, clam or mananose, using artificially impregnated eggs for the purpose, which were dealt with the same as those of the oyster.

An earnest, and, it is to be hoped, successful effort is being made by the United States and Maryland Fish Commissions to introduce the most approved French methods into the waters of Maryland and to supplement these by even more advanced methods, if practicable. The results of the observations and experiments of the writer during the last two years have been embodied in part in a report to the Maryland commissioner for the year 1881, which has been favorably received. Additional papers have been contributed for the same report for 1882, and to the bulletin of the United States Fish Commission, bearing mainly upon the anatomy, finer structure, and development of the animal. An imperfect list of the published works on the subject has also been compiled by the writer; a more complete catalogue of the literature of the subject in all languages will shortly be published by the Dutch Government.

What has already been put upon record it will not be worth while to discuss, and we will therefore recapitulate only where necessary, adding sundry new facts not yet recorded. To our knowledge of the early development of the animal we have added nothing. The account given by Brooks for the American, by Salensky, Gerbe, Fischer, and Davaine for the European, species, with little qualification, remains the same. The detachment of the ring or crown of vibratory filaments or cilia from the embryo oyster as asserted by Davaine has not been confirmed by any other observer. Hatschek has lately contributed some valuable researches in regard to the development of young bivalves. Working, however, upon the embryo ship-worm, his studies have no direct bearing upon the oyster, but they nevertheless throw considerable light upon the mode of development of the gills, upper gill cavities, liver, muscles, foot and nervous system of the great group to which both belong. This last research shows that the conversion of a part of the velum or ciliary crown above the mouth into palps and gills, as held by Lankester, does probably not take place. The occurrence of ciliary bands running from the edge of the mantle on its inner side to the mouth, as observed by the writer in spat one-eight of an inch in diameter, was supposed at first to confirm Lankester's view, but Hatschek's researches have made such an opinion untenable. The physiological function of the bands was, however, clear; by the vibration of the filaments composing them they establish currents towards the mouth, which hurl the food of the young spat into its spacious throat, serving in part the same purpose as the velum adjoining the mouth of the fry.

Brooks has represented the freshly laid ova of the oyster with a spherical nucleus and nucleolus; the former is large, clear, and spherical, and is embedded near the center of the egg; the nucleolus is situated inside of the nucleus in a somewhat eccentric position. I do not find the latter spherical, but formed as if composed of a larger and smaller highly refringent pair of spheres partly fused with each other, or of the same form as the nucleoli of the eggs of *Anodonta*, as described by Flemming, and somewhat similar to those of the slipper limpet (*Crepi-*

dula glauca), as observed by the writer. Some very singular figures of the eggs of the European oyster in Poli's *Testacea siciltæ*, published in 1795, renders it not improbable that he may have seen this singularly formed nucleolus.

The ova are not all "ripe" in all cases at the same time in the same ovarian tubules. The same condition of affairs is found in the ovary of the oyster as was observed in that of *Scrobicularia* by Von Jhering; that is, while some ova were mature others in the same tubule or follicle were still very immature. The condition of the ovary varies, however, considerably in different individuals; in some cases the most of the ova are ripe at about the same time, in others there is a greater difference between the time of maturity of different eggs. It is also frequently observed that a portion of the generative organs of the same oyster are much more advanced in maturity than other portions. The ovaries and spermaries are never entirely wasted away or atrophied, as would appear to the naked eye. The full, enlarged appearance which is noticed when the generative glands are full of ripe products is often due to a distension of the ducts which lead away from the tubules or follicles, and when this is the case, if the handle of a scalpel is gently stroked over the distended ducts over the side of the animal, from its head end towards the posterior portion below the muscle, the ova or spermatozoa, as the case may be, can be forced out of the open end of the main efferent generative duct into the upper gill chamber of its own side, into which the former opens, as described in the anatomical outline sketch given in my report to the Maryland commissioner for 1881, page 15.

It has recently been asserted by some Dutch investigators that the generative products were not discharged by way of a single duct on either side of the animal, as described by Lacaze-Duthiers. What anatomical grounds these observers have for this statement I do not know; they appear to have been investigating the structure of the animal by means of thin slices or sections. The simple experiment with a sexually ripe oyster, as described above, has invariably given the same result; never more than a single opening was found on one side from which the eggs were seen to issue. So far thin sections of the oyster as observed by me have not shaken my belief in the accuracy of the observations of Lacaze-Duthiers, nor have I seen any evidence of three generative openings and ducts on either side of the European oyster, as asserted by Davaine, nor is it worth while to more than notice Home's error with regard to the water-chamber above the gills, which he regarded as the oviduct.

At the time the oyster is full of spawn, the generative organ completely envelops the viscera (liver, intestine, and stomach) except a small portion at the anal end of the intestine, and the head end of the visceral mass. All of the deeper tubules or follicles composing the generative gland trend towards, and join directly or indirectly the main duct on either side of the body, into which they pour their products as the latter are received from the canalicular structures in which they are matured. At no time do we find the generative organs quite undeveloped. If they are not apparent to the eye in winter, sections show the ducts and microscopic rudiments of germinal follicles or tubules, as a net-work of strands of minute germinal cells, which traverse in all directions the coarse superficial layer of vesicular connective tissue cells, miscalled the "fat." As the breeding season approaches, the minute germinal cells of this net-work of rudimentary reproductive cells commence to grow until they attain the development observed in the animal when full of spawn. The ducts or follicles are never developed in the mantle, but the substance of the latter may come into contact externally and superficially with the generative organs.

The terms "fry" and "spat" I have endeavored to use in such a way as to avoid confusion. As soon as the egg has developed far enough to move about by means of the fine motile filaments with which it is partially covered, it may be considered to have reached the fry stage of development, and to have *hatched*, but it is to be borne in mind that an oyster egg does not hatch in the same sense as does the egg of a chick or fish, that is, by breaking its egg shell or membrane, because the oyster egg is without a membrane such as must be cast off in the act of hatching in the former cases. As soon as it has ceased to rove about in the water, and has fastened itself to some other object, it has attained the stage of development known to oystermen by the term "spat."

Our researches (see Maryland Report, 1881) show that the dimensions of the fry of the American oyster at the time it ceases to be "fry," fixes itself, and becomes spat, is about one-eightieth of an inch, and at that time the valves are characterized by a very remarkable symmetry, which is departed from as soon as the growth of the shell begins in its new fixed position. The manner in which this attachment is made has not been learned, but it is very probable that this is accomplished by means of a larval byssus. Such a conclusion appears to be warranted by the fact that the larvæ or swimming young of most of the allies of the oyster are provided with a byssus or threads for their temporary anchorage, such as may be seen very strongly developed in the adult salt-water mussel.

All theorization in regard to the nature of the mechanism of fixation aside, however, it now becomes a question of the most profound importance for us to endeavor by experiment to maintain artificially impregnated oyster eggs alive for a long enough time after they begin to swim, so that they may have an opportunity to attach themselves. The experiments of those who have hitherto worked upon the development of the oyster have shown us that this is exceedingly difficult to do, and that beyond the present stage of our knowledge and experience much still remains to be achieved. Various forms of apparatus have been tried with indifferent success. The experiment of using bibulous paper diaphragms through which the sea-water was allowed to pass was a failure; the pores of the paper soon became clogged with fine sediment, so as to stop the flow of water. Bolting-cloth does not have the meshes fine enough to hold the eggs; besides, it is expensive and not durable. The use of a membrane of filtering paper, with nickel-plated wire cloth above and below the paper in order to strengthen it, and forming the bottom of hatching-boxes placed inside of another and larger box from which the sea-water was allowed to escape rapidly through an intermittently active siphon, and constantly run in very slowly, was found to clog, as in apparatus where the flow was only in one direction. Although the contrivance was automatic, as the outer box filled up, the inflow into the inner box with the porous bottom containing the eggs was interfered with both by the swelling of the fibers of the paper as well as by the accumulation of slimy sediment in the substance of the latter. The outflow from the inner boxes through their porous bottoms was then impeded from the same causes, and as the siphon emptied the outer box the water in the inner boxes would not fall quickly enough to effect any considerable change. Filtering the water did not seem to help matters sufficiently to make it an object to filter a supply for the purpose. Here our experiments have broken down completely, and all the results so far reached with such apparatus have not been of sufficient value to make it desirable to repeat them in the same way, though they have been conducted with three different forms of apparatus.

Recently Prof. S. I. Smith, of Yale College, has succeeded in incubating the eggs of certain crustaceans in shallow plates without changing the water at all, but by simply aerating and keeping it in constant circulation by means of jets of air playing constantly upon its surface. This mode of hatching appears to fulfill the requirements of the case fully, as far as I can now see, and it will be of the greatest importance to test this method at the earliest possible opportunity. By its use we will be enabled to avoid the loss of eggs which would follow from the use of any method in which there is a current of water constantly running in and flowing out of the incubating contrivance.

Should we be able to artificially incubate the eggs of the oyster and keep them alive until the time when the embryos attach themselves to foreign objects, we will have attained such a success as will probably never be paralleled in any other branch of fish culture. The artificial impregnation of the eggs of the oyster may be accomplished to the extent of thousands of millions; and, should it be found possible to keep their hosts of young alive until they had passed certain critical periods of their embryonic existence, we would have practically succeeded in adding so many millions of spat to those already existing, from which seed might be supplied for the foundation of extensive beds where oysters had been previously unknown.

Brooks, in carrying his embryos along for the period of six days, encountered the same difficulties as myself. If, as I have good evidence for premising, when the young oyster ceases its wandering habit its valves measure one-eightieth of an inch in their longest diameter, we have yet to find out how old it is when of this size. When we learn this we will know how long it will be necessary for us to keep the young in the incubating apparatus. We can reach the answers to these questions only by the use of the proper sort of hatching arrangement, in which artificially impregnated eggs are used, being careful, of course, to keep accurate records of the time of impregnation and the fluctuations of temperature of the air and water during the progress of the experiment. With the finer questions of the anatomy of the embryos we will have little to do; in fact, I do not see that they will help us much in the comprehension of how the hatching process is to be conducted, which goes without denying, however, that the experienced embryologist must be expected to determine whether the development is progressing properly. When once the development has been carried to the stage of fixation the embryologists will have an abundance of opportunity to make out the finer details of structure, and let us remark in regard to the oyster, one of the most accessible of animals, that much still remains to be done by both the anatomist and embryologist.

Whatever may be the form of the apparatus which will finally be used in artificial oyster culture, it will also be necessary to provide some sort of cheap and effective method of providing for the attachment of the young fry to some substance or object which may be transferred to *nurseries*, where the spat is to undergo further development. This *cultch*, or collecting apparatus, must be suitable for immersion in the shallow incubating vessels among the developing fry. Clean pebbles, graded through a sieve of the proper mesh, at once suggest themselves as admirably fitted for the purpose, but what is most suitable will have to be learned by experiment. To facilitate the study of the spat immediately after fixation, slips of glass and mica, arranged so as to depend into the water in the hatching apparatus, would probably provide the microscopist with very young fixed stages, which could be transferred to the stage of the microscope without disturbing their attachments, the nature of which could then be readily ascertained on such transparent cultch.

The special merit of the proposed method of artificial culture from the egg upwards would be that we could probably do without the cumbrous tiles, slates, &c., covered with mortar, such as are used abroad. In fact, if *collectors* are to be used at all after the French mode, it would seem to the writer that it would be just as well to use old oyster shells and the cheapest possible materials strewn over arable bottoms near productive spawning oyster beds, as is pretty extensively practiced on the coast of New England, especially Connecticut, and, to some extent, in places on the Chesapeake Bay. If any considerable advance is to be made in the culture of the oyster, it will be by a radical departure from a class of methods which have been in use for over ten centuries. The old method is founded on well-ascertained natural principles, and there is no reason why more modern discoveries should not greatly increase the effectiveness and radically change the manner of the propagation of this most valuable of all food shell-fish. Besides, the great cumbrousness of tiles, &c., involves a great outlay of labor, such as would be a serious item in their practical utilization in the United States, where labor is much more expensive than in continental countries. Not only is this objection valid, but a still more serious one is the uncertainty of the set of spat, which catches on any sort of natural or artificial cultch. In some seasons the collectors will be overcrowded, in others no spat will be found to adhere. The same element of risk is encountered in the use of old oyster shells as cultch for the spat, and, as I have been told by oystermen of large experience, several thousands of dollars' worth of shells may be strewn upon good oyster bottom, upon which not a single spat will be found at the end of the season, thus involving a loss of both material and labor. I do not see that any method in which tiles or mortar-covered slates are used will be a particle more likely to afford a nidus for spat than old shells or the cheapest kind of cultch, except in some places where the latter is liable to be covered with mud or sediment.

This uncertainty, it appears to the writer, can be overcome by a totally different method of procedure. We must have the temperature of the water and conditions of the artificially fertilized and confined embryos under control. The uncertainty which has hitherto attended oyster propagation must disappear measurably in the face of intelligent experiment, and it is to be hoped that in a few years we will hear of oyster nurseries or incubating establishments in successful operation, from which millions of spat will be annually bred from artificially impregnated eggs to be sold as seed to planters, who will enter upon the business of oyster cultivation on an entirely new and scientific basis. Whether all that we have pictured can be realized may be a matter of doubt with many, but at any rate it is a stage of the oyster industry which, if possible of attainment, ought at once and vigorously to be striven for under the auspices of both public and private enterprise. Unlike the propagation of many kinds of fishes, the results of oyster culture can be watched from the earliest fixed stages onwards and progress noted; they do not, like fishes, move about from place to place, but after fixation may be kept under observation in the same situation until they have reached a marketable size. This is a most satisfactory feature of the work, and ought to attract observers.

Of no less moment than the introduction of radically new and more certain methods of propagation is the question, upon what materials does the oyster feed? How does its different kinds of food affect its flavor and appearance? What are the conditions which will most quickly bring it into a plump, marketable condition? The most contradictory and confusing statements are made by different persons in regard to the feeding habits of the animal, and anomalous as some of them may at first appear, many of them doubtless have some foundation in substantial fact.

Professor Leidy, before the Academy of Natural Sciences of Philadelphia, has recently stated it as his belief that oysters probably feed on the zoöspores of certain algæ, such as those of *Ulva latissima* (sea cabbage), which he knew from personal observation to be green, and which he thought might possibly be the cause of the green coloration of the soft parts of the animal frequently observed in both the American and European species, and which, I am convinced from observation, originates from the same source in both species. Very possibly the spores of *Ulva* may be the cause, but, judging from what I have seen and heard from oystermen, as well as from what I have read in various publications relating to this matter, I am not inclined to regard this as the only source of the green observed in the oyster. Without being able to state positively what it is, we may take it for granted that the color is of vegetable origin, and therefore quite harmless. That it is not copper we may be equally certain, for any such quantity of a copper salt as would produce the green gills and patches on the mantle, such as are often observed, would without doubt be as fatally poisonous to the oyster as to a human being. The source of the green has recently been investigated by two French savants, MM. Puysegur and Decaisne, who found that when perfectly white-fleshed oysters were supplied with water containing an abundance of a green microscopic plant, the *Navicula ostrearia* of Kützing, their flesh acquired a corresponding green tint. These investigators also found that if the oysters which they had caused to become impregnated with this vegetable color were placed in sea-water deprived of the microscopic green vegetable food, the characteristic color would also disappear. Whether this will finally be found to be the true explanation remains to be seen, as some recent investigations indicate that it is possible that a green coloration of animal organisms may be due to one of three other causes besides the one described above as the source of the green color of the oyster. Patrick Geddes, in a recent number of *Nature*, has pointed out that "the list of supposed chlorophyl containing animals * * * breaks up into three categories: first, those which do not contain chlorophyl at all, but green pigments of unknown function (*Bonellia, Idotea, &c.*); secondly, those vegetating by their own intrinsic chlorophyl (*Convoluta, Spongilla, Hydra*); thirdly, those vegetating by proxy, if one may so speak, rearing copious algæ in their own tissues, and profiting in every way by the vital activities of these." The last is one of the most interesting and important of modern biological discoveries, that living animal bodies may actually afford a nidus for the propagation of green microscopic plants, and not be injured but rather be benefited thereby. The oxygen thrown off by the parasitic vegetable life appears to be absorbed by the tissues of the animal, while the carbonic dioxide gas thrown off by the latter is absorbed by the vegetable parasite, thus affording each other mutual help in the processes of nutrition and excretion. This singular association and interdependence of the animal host and the vegetable guest has received the somewhat cumbrous name of *Symbiosis*, which may be translated pretty nearly by the phrase associated existence. This is not the place for the discussion of the purely scientific aspect of this question, as already ably dealt with by Dr. Brandt, Patrick Geddes, Geza Entz, and others, and we will therefore only notice their researches in so far as they appear to have a bearing upon the origin of the green color of the oyster. Entz has discovered that he could cause colorless infusoria to become green by feeding them with green palmellaceous cells, which, moreover, did not die after the death of their hosts, but contined to live growing and developing within the latter until their total evolution proved them to be forms of very simple microscopic green algæ, such as *Palmella*, *Glœocystis*, &c. (E. P. Wright). My own observations on some green microscopical animals have been of so interesting a character, that I will here describe what I observed in a green bell-animalcule. Next the cuticle or skin in the outer layer of their bodies, in all stages, a single stratum of green copuscles were found to be uniformly embedded, like the chlorophyl grains observed as a superficial layer in the cells of some plants—as in *Anacharis*, for example. The same arrangement of the green corpuscles had been observed in *Stentor*, the trumpet-animalcule, many years before, by Stein. There may be parasites, as observed by Dr. Entz, but, judging from their superficial position, their globular form, and behavior towards reagents, the absence of a nucleus or of any cleavage stages, they must, it seems to me, be regarded as integral parts of the creatures in which they are found.

A grass-green planarian, *Convoluta schultzii*, found at Roscoff by Mr. Geddes, was discovered by him to evolve large amounts of oxygen like a plant, and "both chemical and histological observations showed the abundant presence of starch in the green cells, and thus these planarians, and presumably, also, *Hydra*, *Spongilla*, &c., were proved to be truly vegetating animals." Similar facts have since been observed in relation to other green animals by the same naturalist.

That the green observed in a number of animal organisms is of the nature of chlorophyl, or leaf green, has been proved by Lankester (see Sach's Text-book of Botany, p. 687), by means of the spectroscope. A. W. Bennett, in alluding to Lankester's observations, says: "In all cases the chlorophyloid substance agrees in having a strong absorption band in the red—a little to the right or left; and except in *Idotea*, in being soluble in alcohol, and in having strong red fluorescence, and in finally losing its color some time after its solution.

The vegetable organisms which have been found to inhabit the lower forms of life alluded to above have been regarded as belonging to two genera by Dr. Brandt, which he has named *Zoöchlorella* and *Zoöxanthella*, and which are probably synonymous with the genus *Philozoön* proposed by Mr. Geddes. But the latter claims to have demonstrated the truth of the view that the yellow cells of radiolarians and polypes are algæ; secondly, the foundation of the hypothesis of the lichenoid nature of the alliance between algæ and animal into a theory of mutual dependence; and, thirdly, the transference of that view from the region of probable speculation into that of experimental science.

Hitherto no one has, apparently, noticed the occurrence of green vegetable parasites in bivalve mollusks except Professor Leidy, who has kindly permitted me to use the facts observed by him relating to *Anodon*, one of our common fresh-water mussels. In this animal he observed what he regards as algous parasites, living within the cells of the tissues of the molluscan host, larger than nuclei of the cells of the latter, and lodged in clusters in their paraplasm. These facts, observed a long time since, render it very probable that Professor Leidy was one of the first, if not the first, to notice the intracellular parasitism of a plant in an animal.

Amongst some oysters which were obtained from England through the kind offices of Messrs. Shaffer and Blackford, in response to a request coming from Professor Baird, certain ones were found which were decidedly green. Of these the French specimens of *Ostrea edulis* and a singular form labeled "Anglo-Portuguese" had the gills of a greenish hue, and in some of the latter the liver, heart, and mantle was very deeply tinged in certain parts, so much so that I decided to make as critical an examination as my resources could command at the time. Spectroscopic investigations gave only negative results, as it was found impossible to discern any positive evidence of chlorophyl from the spectrum of light passed through thin preparations of some of the green-tinted portions of oysters, some of which, like those made from the heart, were decidedly green to the naked eye. There was no absorption noticed at the red and blue ends of the spectrum, such as is observed when the light which enters the slit of the spectroscope first passes through an alcoholic solution of leaf-green or chlorophyl. Indeed, the spectrum did not appear to be sensibly affected by the substance which causes the coloration of the oyster. No attempt was made to still further test the matter with the use of alcoholic green solutions obtained from affected oysters, as the former were not obtainable with a sufficient depth of color because of the relatively small amount of coloring matter present in the animals. If any of the coloring matter was derived from diatoms the spectrum of phycoxanthine was also not developed. Unstained preparations of the natural green hue were used in all of these experiments. Some unstained balsam preparations of the green portions, especially of the heart, showed that the color, which was at first localized and confined to the green cells, after a while became diffused so as to give the preparation a uniform greenish tinge. This is proof of its soluble and consequently diffusible nature.

Finally, in order to see if the color was due to the presence of copper, Prof. H. C. Lewis, of the Academy of Natural Sciences of Philadelphia, kindly made some delicate tests for me, using small dried fragments of an oyster very deeply tinged with green in various regions, especially in the liver, connective tissue, and mantle. The fragments were burned in a bead of microcosmic salt and chloride of sodium on a clean platinum wire in a gas flame. This test did not give the characteristic sky-blue flame which should have been developed had there been the minutest trace of copper present. This portion of the research I since find was superfluous, as Professor Endlich, of the Smithsonian Institution, in 1879, had already gone over the same ground chemically, making every test he could think of to learn whether there was any metallic or other poisonous substance present in some green oysters which had been submitted to him by the health officers of Washington, who supposed that they might contain something unhealthful, and should therefore be excluded from the market. Professor Endlich, however, found nothing that he considered hurtful.

Sachs, in his Text-book of Botany, p. 222, says: "The diatoms are the only algæ, except the Conjugatæ, in which the chlorophyl occurs in the form of discs and bands, but in some forms it is also found in grains, and the green coloring matter is concealed, like the chlorophyl grains in Fucaceæ, by a buff-colored substance, diatomine or phycoxanthine."

It appears, then, according to the foregoing quotation, that it is not impossible for diatoms to be the cause of the green color in oysters, and that the objections urged by some against them as a cause of it is founded on a misapprehension of their structure. I find that the liver is normally of a brownish-red color in both the American and European oysters, but that it often has a decidedly greenish cast in green ones, and that this is due not to a parasitic animal or plant, but to a tinction or stain which has affected the internal ends of the cells which line the follicles or ultimate saccules of the liver. This color is able to survive prolonged immersion in chromic acid and alcohol, and does not allow carmine to replace it in sections which have been stained with that color, the effect of which is to produce a result similar to double staining in green and red. The singular green elements scattered through the connective tissue remain equally well defined, and do not take the carmine dye. I at first believed the green cells to be parasitic. I also supposed that starch granules were apparent, but physical tests failed definitively to reveal them. The large and small green granular bodies in the connective tissue and those close to the intestinal wall I find present in white-fleshed oysters, but simply with this difference, that they are devoid of the green color. It is therefore evident from this simple fact that they cannot be of the nature of parasites, though the color is primarily limited to them only. This condition observed by me in various specimens of American and European oysters does not, however, disprove the possibility of the occurrence of vegetable parasites in these animals.

In some very "poor" Falmouth oysters very much affected with green coloration the gills, heart, and mantle were most notably colored. Some of them were tinged with an unusual depth of color, so much so that to one unacquainted with the cause they would doubless have been repulsive, and unlikely to have stimulated any gustatory feelings. In one of these I found a large cyst or sack near the edge of the mantle, and forming a cavity in its substance one-half inch in length by one-fourth in width. The hearts of the affected specimens were found to have their walls apparently thicker than those of unaffected ones, the muscular trabeculæ which interlaced on the inside were found to have entrapped and held in their meshes vast numbers of the loose, green cells precisely like those which freely escaped from the cyst alluded to above. These green cells were quite as independent of each other as the ordinary discoidal corpuscles in the serum of the red blood of a vertebrate. The green cells were sometimes confined to the anterior or the posterior wall of the ventricle, sometimes to its upper or its lower end, sometimes the entire ventricle was so loaded with them as to render it quite opaque when viewed with transmitted light. These cells under high powers were invariably found to have about the same appearance; were of about the same size, with a distinct nucleus placed eccentrically; frequently with evidence of pseudopodal prolongations extending laterally from the sides. The nucleus could be very nicely demonstrated with iodine or acetic acid as a refringent, globular body one six-thousandth of an inch in diameter. The dimensions of the cells would average about one two-thousandth of an inch, or one-fourth of the size of the connective tissue cells. Now for their identification, which was accomplished as follows: An application of the well-known crucial test for starch gave a negative result. When iodine was first applied to the cells in strong solution, and afterwards treated with sulphuric acid, with the result that the characteristic blue reaction was not developed, showed that there was no cellulose wall covering them, and that they were not parasitic algous vegetable organisms. In potassic hydrate they underwent complete solution, a further proof of the absence of cellulose and their non-vegetable character. Their dimensions, one two-thousandth of an inch, is about that of the blood-cell of the oyster. The nucleus is in the same position as in the blood-cell of the animal. Their usual occurrence in the gills and frequent presence in the heart, caught in the meshes of the muscular trabeculæ of its wall, is almost positive proof of their true origin and character. Furthermore, I find in sections that they sometimes occlude the blood-channels, or are adherent to their walls. In the cyst in the mantle, as in the heart, they are free, and in the normal untinged heart they are not abundant. All of the foregoing facts indicate that these green bodies are in reality blood-cells which belong to the animal. How they became green is not easy to determine without a careful examination of some of the localities where such green oysters are plentiful. The fact that I found instances in green oysters where a greenish material was found in the follicles of the liver, the lining cells of which were also affected, would indicate that the color was probably absorbed from the food of the animal, which, as we know, consists largely of vegetable matter. The green coloration of the liver, I am convinced, is not due in such instances to a hepatic secretion, which, by the way, is not normally of this color in the oyster. It is not improbable that the blood-cells imbibing the color from the tinged nutritive juices transuded through the walls of the alimentary canal acquired the color of the food which has been dissolved by the digestive fluids. How to account for the accumulation of the green cells in the heart and in cysts in the mantle is also a difficult question, unless one be permitted to suppose that the acquisition of the green color by the blood-cells is in reality a more or less decidedly diseased condition, for which we again have no ground in fact, since the green oysters are apparently in as good health as the white ones. They are found "fat" or "poor," just as it may have happened that their food was abundant or the reverse.

If it be objected that the green color indicates an unhealthful condition of the animal, it may be stated that still other color variations of the flesh have fallen under my observation recently. What I allude to now is the yellowish, verging towards a reddish cast, which is sometimes noticed in the gills and mantle. This, in all probability, like the green color, is due to the reddish-brown matter which is contained in much of the diatomaceous food of the animal. Mr. J. M. Carley has also called my attention to these variations, and was inclined to attribute it to the soil in the vicinity of the beds. But if the classical writers are to be trusted, to the green, yellow, and white fleshed sorts, we must add red, tawny, and black fleshed ones. Pliny tells us of red oysters in Spain, of others of a tawny hue in Illyricum, and of black ones at Circeii, the latter being, he says, black both in meat and shell. Horace and other writers awarded these black oysters the palm of excellence (O'Shaughnessy). However, the black appearance may have been due to an abundance of the natural purple pigment in the mantles of the animal, which varies very much in different species; some, judging from the dark purple color of the whole inside of the shell, must have the whole of the mantle of the same tint. The amount of color in the mantle, especially at its border, varies in local varieties of both the American and European species, as may often be observed.

As to the culinary value of green oysters my own experience has indicated that as far as their taste is concerned they are not perceptibly inferior to the white-fleshed ones. While in New York recently I was enabled, through the kindness of Mr. J. M. Carley, to test the comparative eating qualities of the two sorts pretty satisfactorily. When stewed, no difference was perceptible to the taste, and not the slightest suspicion of an acrid metallic flavor could be detected, such as would have undoubtedly been perceptible had copper been present in poisonous quantities. Professor Leidy about the same time tried a similar experiment with the same result, concluding that the difference in quality between the white and green fleshed sorts was imperceptible to the taste. In conversation with a restaurateur quite recently, the latter volunteered the information that he was in the habit of selecting the green-fleshed oysters for his own eating, declaring that they were perceptibly superior, in his estimation, to the white ones. This is the only instance that has come to my knowledge where the preference was given to the green oyster, as appears to be the case in England and on the Continent.

Without having made any special effort to collect data regarding the occurrence of green oysters on the coast of the United States, I may say that they are probably quite as common here as in Europe, and that the cause is the same; at any rate it is certain that many more "greened" oysters are consumed in the restaurants of eastern cities than is generally supposed. During the last three years I have found that they occur almost everywhere along the eastern coast. Amongst the localities may be mentioned, Lynn Haven Bay, York and Hongres Rivers, Virginia. I have been told that they occur along the Atlantic coast of Maryland and Virginia, as at Chincoteague Island, for example. I am informed by Mr. Carley that they also occur in New York Bay and Long Island Sound; in fact I have seen some from those localities. A Philadelphia dealer also tells me that they occur on the coast of New Jersey, both in the vicinity of New York and along the southern portion. I have met with them in a number of instances in saloons where it was impossible to trace them to the beds whence they came. In every case they presented the same appearance as those which I have seen from abroad. The European oysters which have fallen under my observation, and which were most affected, were the French, Falmouth, and Portuguese sorts.

The most important glandular appendage of the alimentary tract of the oyster is the liver. It communicates, by means of a number of wide ducts, with somewhat plicated walls, with a very irregularly formed cavity, which we may designate as the stomach proper, in which the food of the animal comes into contact with the digestive juices poured out by the ultimate follicles of the liver, to undergo solution preparatory to its absorption during its passage through the singularly-formed intestine. If thin slices of the animal are examined under the microscope, we find the walls of the stomach continuous with the walls of the great ducts of the liver. These great ducts divide and subdivide until they break up into a great number of blind ovoidal sacs with longitudinally folded parietes, into which the biliary secretion is poured from the cells of their walls. A thick stratum of these follicles surrounds the stomach except at its back. It is not quite correct to speak of the liver of the oyster as we speak of the liver of a higher warm-blooded animal. Its function in the oyster is the same as that of three different glands in us, viz, the gastric follicles, the pancreas, and liver, to which we may possibly add the salivary, making a total of four in the higher animals which are represented by a single organ in the oyster. In fact experiment has shown that the secretion of the liver of mollusks combines characters of at least two if not three of the glandular appendages of the intestine of vertebrated animals. There are absolutely no triturating organs in the oyster for the comminution of the food; it is simply macerated in the glandular secretion of the liver and swept along through the intestine by the combined vibratory action of innumerable fine filaments with which the walls of the stomach, hepatic ducts, and intestine are clothed. In this way the nutritive matters of the food are acted on in two ways: first, a peculiar organic ferment derived from the liver reduces it to a condition in which it may be absorbed; secondly, in order that the latter process may be favored it is propelled through an intestinal canal, which is peculiarly constructed so as to present as large an amount of absorbent surface as possible. This is accomplished by a double induplication or fold which extends for the whole length of the intestine, the cavity of which, in consequence, appears almost crescent-shaped when cut across. On the concave side, the intestinal wall on its inner face is thrown into numerous very narrow, longitudinal, and interrupted folds, which further increase the absorbing surface. Such minor folds are also noticed in the stomach, and some of these may even have a special glandular function. There are no muscles in the walls of the intestine as in vertebrates, but the sole motive force which propels the indigestible as well as digestible portions of the food through the alimentary canal is exerted by the innumerable vibratory cilia with which its inner face is clothed.

This apparatus is admirably suited to render the microscopic life found in the vicinity of the animal available as a food supply. The vortices created by the innumerable vibratory filaments which cover the mantle, gills, and palps of the oyster, hurl the microscopic edible hosts down the capacious throat of the animal, to undergo conversion into its substance, as described above. The mode in which the tissues may become tinged by the consumption of green spores, diatoms or desmids, it is easy to infer from the foregoing description of the digestive apparatus of the animal. The colorless blood cells, moving in a thin *liquor sanguinis*, would, judging from their amœbiform character, readily absorb any tinge acquired by the latter from the intestinal juices. The color in them is, however, homogeneously distributed through the substance of the green cells, and is not due to the presence of any organisms or particles within them. No bacteria or putrefactive organisms were ever observed by me in oysters except in such as were spoiled or putrid.

I have discussed in another place, in a desultory way, the microscopic marine fauna of the Chesapeake Bay, where I have been engaged upon the study of the oyster under the auspices of the United States and Maryland Fish Commissions, but what I have done has been simply preliminary, and necessarily incomplete. Before we are ready to deal with the matter on which the oyster feeds, we desire a more perfect acquaintance with the microscopic life which grows upon the oyster beds and swims about in the adjacent waters. From the fact that the lower forms of life in fresh water often appear in great abundance one year, while in the next, from some unexplained cause, none of the same species will be found in the same situation, we may conclude that similar seasonal variations occur in the facies of the microscopic life of a given oyster bed and its vicinity. Such yearly variations in the abundance of microscopic life are probably the causes of the variable condition of the oysters taken from the same beds during the same season of different years. Violent or sudden changes of temperature are probably often the cause of the destruction of a great amount of the minute life upon which the oyster feeds. Backward and stormy seasons probably also affect the abundance of the microscopic life of the sea. All of these questions have, however, as yet, been scarcely touched, and, judging from the disposition of many of our students of zoology to be content merely with a description of new species and the compilation of lists, instead of also entering into the life-histories, relative abundance of individuals, and the influence of surrounding conditions upon the forms they study, it will take some time yet before we get the information so much desired. When we arrive at this knowledge we will know why it is that oysters taken from a certain bed are in good condition for a season or two, and then for one or more years are found to be watery and of poor quality, as well as why it is that the oysters of certain beds, which for years have had a high reputation for their fine qualities, are suddenly found to be more or less green in the beard, as I have been informed is now the case with the oysters of Lynn Haven Bay, Virginia.

Speaking of the abundance of the *Navicula ostrearius* Kützing, Mr. Benjamin Gaillon, in 1820, said that they inhabit the water of the tanks or "parks" in which the oysters are grown in France in such immense abundance at certain periods of the year that they can only be compared to the grains of dust which rise in clouds and obscure the air in dusty weather. Dr. Johnston, speaking of the French oysters, says that, "in order to communicate to them a green color, which, as with us [in England], enhances their value in the market and in the estimation of the epicure, they are placed for a time in tanks or 'parks,' formed in particular places near high-water mark, and into which the sea can be admitted at pleasure by means of sluices; the water, being kept shallow and left at rest, is favorable to the growth of the green *Confervæ* and *Ulvæ*, and with these there are generated at the same time innumerable crustaceous animalcules, which serve the oysters for food and tincture their flesh with the desirable hue." Without stopping to criticise the statement regarding the crustaceous food of the oyster, the foregoing extract gives us some hints regarding the advantages arising from the cultivation of oysters in more or less stagnant water, in which, as in the French parks or claires, an abundance of microscopic life would be generated in consequence of a nearly uniform temperature, higher in the early autumn months at least than that of the water of the open sea, where cold currents also would tend to make it still less uniform, and thus interfere with the generation of the minute food of the oyster. In other words, it would appear that the effect of the French method is to furnish the best conditions for the rapid and constant propagation of an immense amount of microscopic food well adapted to nourish the oyster; that, unlike oysters exposed to a rapid flow of water on a bottom barren of minute life, they grow and quickly attain a saleable condition.

In this country narrow coves and inlets with comparatively shallow water appear to furnish the best conditions for the nutrition and growth of oysters, and according to my own meager experience these are the places where we actually find the minute animal and vegetable life in the greatest abundance; and, as might have been expected, the oysters planted in such situations appear to be in good condition early in the autumn, long before those which are found in deeper, colder, and more active water, where their microscopic food has less chance to multiply.

As to the influence of brackish water in improving the condition of oysters, let me observe here that those who hold to that opinion appear to forget to bear in mind the fact that brackish water beds are often in the case just described. Being in shallow, relatively quiet water, an abundance of food is generated, which is rapidly consumed by the animals, which quickly brings the latter into condition, the brackish state of the water getting the credit of the result.

In my report to Maj. T. B. Ferguson, I stated my belief in the practicability of establishing permanent oyster banks or ridges. During the last summer, in the Cherrystone River, Virginia, I saw my idea practically realized. A heap of shells in the river had been scattered so as to form a low, solid elevation, which was alternately covered and uncovered by the rise and fall of the tide. Upon this spat had caught in such multitudes and grown, until the whole in two years was as completely and solidly covered by living, natural-growth oysters as any natural bank I had ever seen. The desirability of using the poorly-grown stock from natural and artificial banks as "seed" for planting appears reasonable, and could no doubt be made profitable where banks of sufficient extent could be established from which a supply of seed oysters could be obtained.

SMITHSONIAN INSTITUTION,
Washington, April 15, 1882.

NOTES ON THE FISHERIES OF GLOUCESTER, MASSACHUSETTS.

By S. J. MARTIN.

[Letters to Prof. S. F. Baird.]

The cod net fishing is done for the year. The amount of codfish caught in nets during this winter was 640,000 pounds. If the codfish had been plentiful the catch would have been very large.